

## COMPARISON OF TECHNIQUES UTILIZED TO DETERMINE MOOSE CALF MORTALITY IN ALASKA

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*Abstract:* Studies to assess causes of neonatal moose (*Alces alces gigas*) calf mortality were conducted in two areas (Nelchina Basin and Kenai Peninsula) of Southcentral Alaska during 1977 and 1978. Equipment, techniques and costs associated with conducting the studies were compared. Calf abandonment was influenced by handling method, length of processing time and strength of cow-calf bond. Abandonment rates were lowest when only the calf was captured and no morphometric and physiologic data were obtained, and highest when both cow and calf were captured and all data were obtained.

Radio transmitters utilized in the studies doubled or tripled their pulse rates whenever they remained motionless for either four or one hour periods, indicating that a mortality had occurred. Mortality of radio-collared calves was determined by monitoring from both fixed-wing aircraft and ground stations. A total of 2,092 visual observations of radio-collared calves was made during these studies, while radio signals alone were monitored on 6,617 occasions.

A total of 104 predator killed moose calves was examined during these studies. Characteristics of calves killed by brown bears (*Ursus arctos*), black bears (*Ursus americanus*) and wolves (*Canis lupus*) are described. The techniques developed during these studies provided reliable data on causes of mortality which would not have been otherwise obtainable.

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In recent years moose populations within several of Alaska's Game Management Units (GMU's) have exhibited downward trends in total numbers (McKnight 1976). Reasons for most of the decline are not known, but low recruitment due to low calf survival prior to November sex and age composition counts has been suggested as the predominant general problem. Specifically, several factors have been suggested which may have contributed to low calf production and survival rates. They included wolf, brown and black bear predation, poor range quality, low bull:cow ratios, and periodic severe winters. The purpose of this paper is to compare various techniques employed to determine causes of moose calf mortality in Alaska.

In an Idaho study (Schlegel 1976), newborn elk (*Cervus canadensis*) calves were radio-collared and monitored to obtain the types of information on calf mortality that we were seeking. Schlegel's technology was adapted for two moose calf mortality studies in Alaska; one in GMU 13 (Nelchina Basin) and one in GMU 15 (Kenai Peninsula). Different techniques were utilized both between and within the studies during the two years (1977 and 1978) in which moose calves were radio-collared and monitored. Ballard and Taylor (1978) described the Nelchina Basin study area while Franzmann and Bailey (1977) described the Kenai Peninsula study area. The Kenai Peninsula Calf Mortality Study was a cooperative effort of the Alaska Department of Fish and Game, Moose Research Center and the U.S. Fish and Wildlife Service, Kenai National Moose Range.

## MATERIALS AND METHODS

## Transmitters

Two brands of radio transmitters were employed during this study. The Kenai Peninsula study utilized radio transmitters and collars designed by the AVM Instrument Company (Champaign, Illinois) during 1977. These radios transmitted a pulsed signal with frequencies ranging from 164.025 to 164.919 MHz and were designed to triple pulse rate whenever the unit was motionless for 4 hours; a fast pulse rate theoretically indicated a mortality had occurred. Collars were fashioned using the design for expanding goose neck bands and were constructed of vinyl plastic (4 cm wide x 2 mm thick). Each transmitter was encased in acrylic and fastened to the collar by vinyl plastic rings through which the collar freely expanded. A 25-cm insulated wire antenna protruded from the encased transmitter and extended along the side of the collar.

During the second year of the Kenai Peninsula study and for both years of the Nelchina Basin study, transmitters utilized were constructed by Telonics, Inc. (Mesa, Arizona). Collars were designed by Schlegel (1976) for elk calves but were modified to accommodate moose. Expandable calf collars constructed of either international orange (used in 1977) or green (used in both 1978 studies) polyvinyl plastic were 10-cm wide by approximately 0.5 mm thick with an inner circumference ranging from 25 to 69-cm. Collars consisted of two strips sewn together by single stitches of standard number 50 cotton thread. The center of the double strip was folded to form a casing for the radio which was then riveted

to the collar through two metal flaps on each side. Nylon elastic 36-cm long and 1.3-cm wide was sewn to the base of the collar between the polyvinyl strips. One side was sewn so the elastic would remain permanently attached and the other side was loosely stitched so the elastic would break away as the collar expanded. Each side of the collar was overlapped at the top and loosely stitched together to permit the collar to break away as the calf grew. On the finished collar, 10-cm up above the rivet, a 5-mm wide piece of nylon elastic 9-cm long was sewn to the inner portion of the collar to facilitate a better fit on newborn calves. This elastic was designed to break away in approximately one month, allowing the calf to grow into the remainder of the collar. The entire collar with transmitter weighed 296 grams.

Each Telonics transmitter (without collar) weighed 170 grams. Transmitters emitted a pulsed signal on frequencies ranging from 148.487 through 148.975 MHz for the Nelchina study and 165.025 to 165.170 MHz for the Kenai study. Transmitters were equipped with a mercury switch "mortality sensor" which doubled or tripled the pulse rate of the signal when the transmitter remained motionless for either a 4 hour period (1977 collars) or a 1 hour period (1978 collars). Power was provided by a lithium battery measuring 24.1-mm by 50.8-mm with an operating voltage of 2.8 VDC providing a theoretical operating life span of 12 to 15 months. Polyvinyl ribbon antennas (1.9-cm wide X 0.09-cm thick X 42-cm long) were between the two polyvinyl strips of the collar, and each transmitter was hermetically sealed in a waterproof metal housing containing internal magnetic switching for storage after use.

## Capture and Radio-collaring of Moose Calves

Three variations of both capturing and processing moose calves were used. A Bell Ranger Jet B helicopter was used to aid in capturing all calves. The variations in capture and handling consisted of: Method 1 - Calf captured and collared with no data obtained; Method 2 - Calf captured and collared with both physiologic and morphometric data obtained; and Method 3 - Both calf and cow captured and collared with both physiologic and morphometric data obtained.

Newborn moose calves were first located from fixed-wing aircraft; then their exact location was relayed by radio to a nearby helicopter. Each helicopter was equipped with a steel rimmed box on each side measuring approximately 0.6 x 1.2-m which served as a platform from which to jump.

When either capture method 1 or 2 was used, the calf was captured by lowering the helicopter toward the cow and calf until the cow fled from the calf. The calf would then either lie down or run before lying down, and the tagging crew would jump to the ground and capture it. The helicopter remained airborne to keep the cow away from the tagging crew.

When capture method 3 was utilized, the cow was first immobilized by administering a combination of 7 mg. etorphine (M-99, D-M Pharmaceuticals, Inc., Rockville, MD), 300 mg. xylazine hydrochloride (Rompun, Cemagro, Kansas City, MO), and 250 units hyaluronidase (Wydase, Wyth Laboratories,

Inc., Philadelphia, PA), with a dart fired from a Cap-chur gun (Nasco-west, Modesto, CA). Once the cow was immobilized, the helicopter was lowered to the ground and the tagging crew then captured the calf which may or may not have been close to the immobilized cow.

Captured cow moose were marked with a colored, numbered visual collar (Franzmann et al. 1974) which permitted individual recognition from fixed-wing aircraft. Each cow was ear-tagged with numbered metal tags accompanied by a 5-cm x 13-cm piece of colored polyvinyl plastic. Tags were affixed to the base of the ear. A lower incisor tooth was extracted from each cow for aging purposes according to the methods described by Sargent and Pimlott (1959).

Each calf was first collared and its sex determined. Under method 1 no further data were obtained except that usually a hair sample was plucked from the back between the shoulder blades to aid in assessing the animal's mineral status using techniques described by Franzmann et al. (1975). When methods 2 and 3 were utilized, several body measurements were recorded. Calves were weighed by placing them in a nylon net with 5-cm stretch mesh and affixing a scale (Overland Nandy Scale #241) to the net. Measurements included total length, heart girth, neck circumference and length of hind foot. The dentition of many calves was photographed.

Samples of blood were taken from the radial vein of each calf and from the jugular vein of adult cows using sterile evacuated containers. Upon returning from the field, the blood was centrifuged and serum

separated and placed into 5 ml plastic vials and immediately frozen. One ml samples were later sent to Alaska Medical Laboratories, Anchorage, Alaska or Pathologists Central Laboratory, Seattle, WA for blood chemistry analysis (Technical Autanalysis SMA-12) and protein electrophoresis (Franzmann and Arneson 1973). Generally one or two 10 ml vials were filled 1/3 to 1/2 full for calves while three to four vials were filled on adult cows. One of the vials contained heparin which provided whole blood for determination of the percent hemoglobin (Hb) with an Hb-meter (American Optical Corporation, Buffalo, NY) and packed cell volume (PCV) with a micro-hematocrit centrifuge (Readocrit-Clay Adam Company, Parsippany, NJ). Remaining sera are being stored for possible future analysis.

Rectal swabs to culture for pathogenic bacteria were taken in the Nelchina study when method 2 was utilized. Swabs were placed in sterile, screw-capped tubes and refrigerated until transferred to the Alaska State-Federal Laboratory, Palmer, Alaska. All samples were cultured on the following media: Blood agar, Eosin Methylene Blue, S S Agar, Brilliant Green Agar, and MacConkey. Enterobacteria were identified by the Enterotube method (R. Barret, pers. comm.).

After tagging and processing the field crews left the calf and/or the cow and calf and met the helicopter away from the site. When the cow was immobilized, an antagonist of diprenorphine (M-50-50, D-M Pharmaceuticals, Inc., Rockville, MD) was administered through the jugular vein. Notes were taken on the cow's reaction to the calf from the helicopter when methods 1 and 2 were utilized, usually 0.2 to 0.4 km away.

We began sterilizing radio collars in the Melchina Basin study in 1977 and 1978, after human scent appeared to be partially responsible for calf abandonment. Processing procedures were also modified in the following ways: (1) helicopter was only used to drive the cow away from the field crew when a charge was imminent; (2) the collars were sterilized before collaring with detergent and ethyl alcohol, and (3) sterilized latex gloves were worn and calves were held in such a manner as to minimize contact with our torsos.

#### Monitoring

Radio-collared calves in the Melchina Basin study were observed from fixed-wing aircraft twice daily for the first two weeks following collaring in 1977. Thereafter and in 1978, and during both years of the Kenai Peninsula study, calves were observed once daily and the radio signal was monitored one additional time per day to detect if mortality had occurred. After the first six weeks of study in both 1977 and 1978 calves were monitored less frequently, averaging once per week up to 1 August and then every 6-8 weeks until radio contact was lost or the collar fell off.

Radio-collared calves were located in the Melchina Basin study using twin three-element antennas mounted on the struts of either a Piper Super Cub or a STOL equipped Cessna 180 aircraft and in the Kenai Peninsula study using twin 4-element antennas mounted on a Piper Super Cub. Tracking techniques were similar to those described by Mech (1974). Both studies used a portable radiotelemetry receiver (A.V.M. Instrument



Company, Champaign, IL). The Kenai study also utilized a portable TR-2 receiver manufactured by Telonics Co., Mesa, AR.

As a supplement to aerially monitoring moose calves on the Kenai Peninsula, a stationary tracking system was established in 1977 at the Kenai Moose Research Center. A Falcon Five receiver (Wildlife Materials, Inc., Carbondale, IL) and a memory unit (W. W. Cochran design) were used with a 30-m high tower equipped with two yagi antennas. The system was designed to relay a signal to the Kenai National Moose Range whenever a fast mode was detected.

When calves were either observed dead or the mortality unit was activated, an aerial search within approximately 1.0 km of the suspected kill site was made when practical in an attempt to sight predators. The presence or absence of radio-collared wolves, brown bears, or black bears were checked. Methods utilized for predator studies were described in Ballard and Taylor (1978), Franzmann and Schwartz (1978), Ballard and Spraker (1979), and Spraker and Ballard, (in prep.). Following the aerial search, a helicopter was used to return to the observed or suspected calf mortality, usually within two hours during the first several weeks of the study. Afterwards, many of the kills were examined using floatplanes.

A two-element, hand held antenna (Telonics Co., Mesa, AR) attached to the portable AVM Instrument Co. (Champaign, IL) receiver was utilized to locate suspected kills. The antenna was held outside the helicopter window, allowing us to pinpoint and often observe the carcass. When kills were not observable from the helicopter, the same antenna was used to locate the carcass on the ground.

Upon reaching the suspected mortality site, a thorough study of the calf and the surrounding area was made to determine cause of mortality. If predation was suspected, the area was searched for presence of tracks and scats. Observations were recorded on a mortality form adapted from Schlegel (1976). In predator related deaths vegetation within a 15-m radius of the kill was thoroughly searched for the presence of hair for use in predator species identification. Hair samples were later independently verified as to species by Mr. Jack Jordan, Investigative Unit of the Division of Fish and Wildlife Protection, Alaska Department of Public Safety, Palmer, Alaska, using a modification of the methods described by Adorjan and Kolenosky (1969).

All of the dead radio-collared calves in 1977 not killed by predators, and initially, a few of those killed by predators were retrieved and transferred to permanent facilities for necropsy. Necropsies in the Nelchina study were performed by Richard Barret, Alaska State-Federal Laboratory, Palmer, Alaska and those in the Kenai study were performed by the second author.

## RESULTS AND DISCUSSION

### Capturing and Processing

A total of 197 moose calves were captured and radio-collared for the two studies during 1977 and 1978; 68 in the Kenai Peninsula study and 129 in the Nelchina Basin study (Table 1). Of this total, 171 calves subsequently retained calf-cow bond. The highest abandonment

Table 1. Comparison of methods used to capture and process neonatal moose calves on the Kenai Peninsula and the Nelchina River Basin of Southcentral Alaska during 1977 and 1978.

Study Area	Study Year	Method 1 <sup>a/</sup>			Method 2 <sup>b/</sup>			Method 3 <sup>c/</sup>			Totals		
		Number Collared	Number Abandonments	Percent	Number Collared	Number Abandonments	Percent	Number Collared	Number Abandonments	Percent	Number Collared	Number Abandonments	Percent
Kenai Peninsula*	1977	0			9	2	22.2	16	4	25.0	25	6	24.0
	1978	31	2	6.5	0			12	5	41.7	43	7	16.3
Nelchina Basin	1977	24	0	0.0	30	6	20.0	0			54	6	11.1
	1978	36	5	13.9	39	2	5.1	0			75	7	9.3
Totals or Weighted Mean		91	7	7.7	78	10	12.8	28	9	32.1	197	26	13.2

a/ Calf only captured--no condition data obtained.

b/ Calf only captured--condition data obtained.

c/ Cow and calf captured--condition data on both obtained.

\* Percent abandonment excludes calves of unknown fate (n = 4).

rate was experienced under method 3, where both the cow and calf were captured and processed. Substantially fewer abandonments occurred when either methods 1 or 2 were utilized.

We suspected that the higher abandonment rate experienced under capture method 3 was the result of a combination of factors. Many of the immobilized cows wandered away from their calves shortly after the antagonist had been administered. Therefore, the drugged condition of the animal probably had some impact. Cows which wandered away from calves nearly always resulted in abandonment. Apparently newborn moose calves could not keep up with a cow under stress, and for unknown reasons, some of the cows did not come back to search for the calves.

We believed that some of the abandonments were partially due to a poorly established cow:calf bond. This appeared to be particularly true for calves which were only a few hours old. We noted that when cows with "newborn" calves were pushed away with the helicopter, they sometimes fled and never made any attempt to return to their calves even when ground time was less than 3 minutes. Conversely, when calves were more than several hours old the cow was persistent in her attempts to return to the calf.

For capture methods 1 and 2 we measured the time it took to successfully collar and process calves. We did this with a stop watch and measured time from departure to return to the helicopter. Ground time for capture method 1 and 2 averaged 5.7 minutes (S.D. = 3.3 min.) and 9.6 minutes (S.D. = 3.02), respectively. Ground time for methods 1 and 2 appeared

to be partially a function of both density of vegetation and experience of participants. Ground time for method 3 in the Kenai study averaged 37.4 minutes (S.D. = 12.2 min.).

In the Nelchina study the abandonment rate under method 2 when the calf was captured and full processing occurred, declined from 20.0 percent in 1977 to 5.1 percent in 1978. Although we have no data to statistically prove our assertion, we believe the changes we instituted in handling collared calves were responsible for the lower abandonment rate. During 1977 we observed at least two cases in which the cow returning to her calf lowered her head and slowed her approach when about 10-m from the calf. The cow then appeared to sniff the calf, bolt backwards and run away never returning. We surmised that we had, by altering the calf's scent, reduced its acceptability to the cow. At this time we modified handling procedures as outlined earlier. Following these changes we only experienced one abandonment out of 15 captures in 1977, and of course experienced the lower abandonment rate in 1978.

Annual costs of capturing each calf in the Nelchina study were \$155.00 and \$175.00 for 1977 and 1978, respectively. Increased costs in 1978 reflected increases in the charter rates for both helicopter and fixed-wing aircraft. Comparative costs per calf in the Kenai study averaged \$197.00. An additional \$58.50 (includes drugs) was required when the cow was also captured and processed. We were unable to do a cost comparison between methods 1 and 2, but since helicopter air time per calf was 68 percent more with method 2, collaring these calves cost approximately 25 percent more than those processed using method 1.

We believe, based upon our comparison of capture and processing methods to abandonment rates that collection of physiologic and morphometric data on both cow and newborn calves definitely increased the likelihood that the cow would subsequently abandon the calf. Some abandonments also occurred when only the calf was processed, but we believe an abandonment rate approaching 10 percent was acceptable for both studies.

Obviously the abandonment rate of 32 percent under method 3 would be unacceptable for most mortality studies. However, the advantages gained from collection of other types of data may make such a high rate of abandonment justifiable. To our knowledge few data exist on the relative health of either cow moose immediately following parturition, or more importantly, newborn moose calves. Aside from determining proximate causes of moose calf mortality, it seems of equal importance to be able to determine the health of the animals at birth, thereby gaining insight as to whether the animal would have lived had the identifiable sources of mortality not been present.

A total of 928 different samples or measurements was obtained for both studies by fully processing captured cows and calves (Table 2). Although these data have only been superficially analyzed to date, we believe they will provide important baseline parameters to aid in assessing moose calf condition at birth. The criteria established by Franzmann and LeResche (1978) for adult moose blood parameters, and Franzmann et al. (1975) for hair mineral analysis as an indicator of mineral deficiencies, all have potential to aid in this assessment. Undoubtedly weight-age correlations will also aid in the interpretation of a calf's health in

Table 2. Types and numbers of biological samples obtained from neonatal moose calves when either both the cow and calf were fully processed or the calf alone was fully processed.

Study area	Year	Weights	Tooth for age determination	Physical measurements	Hair samples	Blood samples	Rectal swabs	
Kenai Peninsula	1977	23	10	154	41	41	0	
	1978	9	13	80	21	21	0	
Nelchina Basin	1977	30	0	117	31	27	15	
	1978	32	0	159	48	36	20	
Totals		94	23	510	141	125	35	928

relation to other regional moose populations. These condition characteristics will also be of value for determining relative health of individual cows in relation to their calves. Consequently we believe that the advantages of the morphometric and physiologic data obtained from processing both cow and calf outweigh the disadvantages of high abandonment at least until an adequate sample is obtained. Once a sufficient sample is obtained or if high initial calf abandonment is deemed unacceptable, then method 2 should be used whenever practical. The abandonment rate obtained when only the calf was captured and fully processed was relatively low in comparison to other methods, yet it allowed collection of several types of baseline information. Additionally, calves which were abandoned in the Kenai Study in 1978 were recaptured and used in captive moose studies.

#### Evaluation of Equipment and Methods of Monitoring

Calf monitoring and subsequent examination of dead calves in the Nelchina study required approximately 250 hours of fixed-wing and 25 hours of helicopter flying time during each year of study. For the Kenai study approximately 140 hours of fixed-wing and 13 hours of helicopter flying time were required for each year of study.

Nelchina Basin calves were visually monitored on 1,308 occasions (Table 3) and the signal alone was heard an additional 2,304 occasions to determine if the mortality sensor had been activated. Kenai Peninsula calves were monitored more intensively than those in the Nelchina study because of the stationary monitoring system. With this system, signals



Table 3. Summary of radio failures and intensity at which radio signals were monitored during moose calf mortality studies conducted on the Kenai Peninsula and Nelchina Basin of Alaska during 1977 and 1978.

Study area	Year	Number of visual observations from aircraft	Number times signal monitored from ground station	Number of times signal monitored w/o visual from aircraft	Number of false alarms	Number of faulty transmitters and/or collars
Kenai Peninsula	1977	455	1,379	675	1	5
	1978	329	1,110	1,149	6	1
Subtotal		784	2,489	1,824	7	6
Nelchina Basin	1977	1,003	0	776	1	1
	1978	305	0	1,528	4	3
Subtotal		1,308	0	2,304	5	4
Totals		2,092	2,489	4,128	12	10

were monitored on 1,379 and 1,110 occasions (Table 3) in 1977 and 1978, respectively. Additionally, Kenai calves were visually monitored a total of 784 occasions while the signal only was monitored from fixed-wing aircraft a total of 1,824 occasions for both years of the study.

During the Nelchina study a total of five false alarms were recorded; one in 1977 when the mortality mode was set for 4 hours and four in 1978 when the mode was set for 1 hour. All of these "false alarms" were the result of calf inactivity. Four radios malfunctioned during the Nelchina study in that the mortality pulse locked on for unknown reasons and did not return to its normal pulse rate. This required visual observation of those calves to determine if mortality occurred. The Kenai study also experienced similar "false alarms" and malfunctions of transmitters; a total of seven false alarms and six faulty transmitters or collars for both years of study. Although both studies had a slight increase in false alarms when the mortality activator was reduced from four to one hour, we recommend its use for moose. The reduction in time span between when mortality occurred and when the unit was activated in all probability aided us in examining dead calves more quickly.

We maintained radio contact with collared calves for as long as possible. For the Nelchina study we maintained contact through November of each year. Following that period we suffered attrition due to premature battery failure, or loss of radio antennas which resulted from the collar splitting in half and exposing the antenna to brush, etc. For the Kenai study radio contact was concluded in August 1977 in response to a combination of mortality, premature failure of AVM radios and from

collars falling off. Collars fell off prematurely due to the plastic collar cracking and breaking. During 1978 radio contact was similar to that in the Nelchina study.

Equipment utilized during these studies was so reliable that we feel once a cow:calf bond was verified, visual observation of calves was not necessary. However, calves were tracked periodically to prevent loss of radio contact due to calf:cow movements. Also visually observing calves on a regular basis increases the probability of observing a predator at the kill site.

During 1977 in the Nelchina study we experienced some problems with the collar designed by Schlegel (1976). It became apparent that the collars as originally designed for elk were not falling off moose. We were able to examine two calves in late fall 1977 and found that collars were splitting apart at the top as intended, but the continuous elastic strip was not parting. The elastic was holding the collar on the calf and when fully expanded was causing lacerations on the neck. No mortality was observed as a result of this problem. We did modify collar design for 1978 by cutting the elastic on the top and sewing it with cotton thread directly to each flap of the collar. This modification solved the problem as the collars were in the process of falling off at the time this paper was prepared.

We utilized three collar colors during the study: both orange and clear plastic in 1977 and green in 1978. Orange colored collars proved most beneficial for aiding us to visually observe the animal from fixed-

wing aircraft. Both the clear and green collars, however, were very difficult to observe from the air, but may have reduced the visibility of the collar to predators.

Our radio transmissions were spaced at 5 MHz intervals. This spacing created problems with separating individual calf frequencies because the AVM LA-12 receiver lacked crystal control and consequently did not have the refinement required to separate signals spaced only 5 Mhz apart. This problem was partially alleviated in the Nelchina study by dispersing the radios over large geographic areas. Collar spacing was not possible in the Kenai study because moose calving was concentrated and serious overlap of calf frequencies was encountered. As a result, a crystal controlled receiver with a programable scanner (TR-2 receiver with digital processor, Telonics, Mesa, AR) was purchased. This new receiver system eliminated frequency overlap reduced fixed-wing flying time when only signals were monitored by at least 60 percent.

We also experienced operational problems with the automated monitoring system (Falcon five receiver and memory unit) on the Kenai and were subsequently unable to rely upon it as much as we had hoped. We should point out, however, that the system does have tremendous potential to reduce costs of monitoring radio-collared moose, particularly in areas where calving is relatively concentrated.

### Determination and Characteristics of Calf Mortality

During our 2 years of study we examined a total of 139 (includes five uncollared calves) moose calf mortalities. We were able to determine cause of the mortality as either being due to predation, accidents or other miscellaneous factors in 135 of these. Of the 135 mortalities, 26 (19.3%) were attributed to project induced abandonments, five of which subsequently were killed by predators, while the remainder were the result of natural causes. Of our identified natural causes of mortality on bonded radio-collared calves, brown bear predation was the largest factor (n = 61, 56.0%) for both studies combined followed by black bear predation (n = 23, 21.1%), miscellaneous (accidents, disease--n = 10, 9.2%), wolf predation (n = 9, 8.3%), and unknown predation (n = 6, 5.5%). We actually observed the predators in 48 (46.2%) of the 104 (includes five uncollared calves) mortalities attributed to predation.

Ground examinations of predator killed moose calves allowed general characterization of kills made by both brown and black bears and to a limited extent wolves. For moose calves which we determined to have been killed by brown bears, we actually observed the predator at the site on 26 occasions. Brown bear kills differed in their characteristics based upon the length of time it took for us to reach the site. Frequently when we reached the site within 2 hours, the brain contents and viscera were all that had been consumed and most of the edible flesh still intact. When this was the case often the ears, eyes and tongue were also missing. Puncture wounds in the neck and skull were readily evident. On occasion claw marks across the body cavity were also

present. When we visited bear kills several hours after the mortality, we often found that the entire carcass along with bones and hoof sheaths had been consumed, except for the lower jaw and cranial bones. On about half of the kills scats usually containing the flesh, hair, bone and hooves of calf moose were located close to the site. Tracks were often present but their occurrence was largely dependent on soil and vegetation conditions at the site. We found that the hide was inverted on approximately 25 percent of the kills, and 25 percent were buried. Brown bear hair was found in varying quantities, on all of these kills where we searched for the presence of hair on the surrounding brush.

Brown bear densities were high and black bear densities low in the Nelchina study area while the reverse was true in the Kenai study area. This facilitated identification of which species of bear was making the calf kills. Where both species of predators exists in reasonable densities the differences in kill characteristics may not be so obvious.

We observed the predator on 12 of 23 black bear killed moose calves. At the kill site we noted perhaps two distinct differences from kills made by brown bears. Black bears usually did not break open and consume brain contents when examined within a short time after the kill; with brown bears it appeared to be the first item sought. Both predator species, however, readily consumed the viscera. Kills by brown and black bears could be differentiated on the basis of hair collected from the kill site, but differentiation was not possible based upon scats.

Although our sample size ( $n = 9$ ) was small, it appeared that the characteristics of wolf-killed moose calves were somewhat different than

bears. Wolves were observed at the kill site on 7 of 9 occasions. At the kill site we found that the brain case had not been broken into and for most, the eyes, ears and tongue were intact. In all cases we found the viscera unconsumed lying either at, or a short distance from the carcass. When flesh was consumed many of the bones were intact or scattered at the kill site. Usually ends of the ribs were chewed off and in some cases ends of long bones and their surfaces were chewed. We only found the presence of scats at three kills; however, this may have been the result of forcing the predator away from the kill. Wolf hair was present on the brush surrounding the kill at all of the sites when we searched for it. We never observed any claw marks on the hide but puncture wounds were always found on either the head, neck or rear quarters.

In conclusion, we believe the techniques we utilized to determine causes of moose calf mortality were reliable and provided accurate data not otherwise obtainable. These techniques have widespread application where quantifiable data on predator-prey relationships are needed, and can be modified to suit other ungulate species.

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